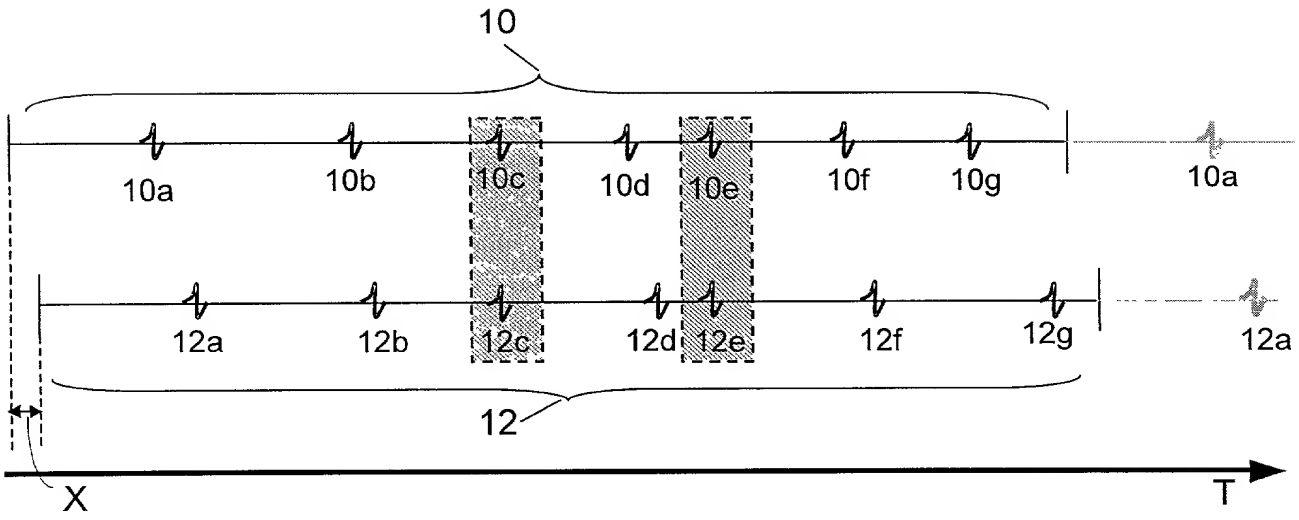

10
10a
10b
10c
10d
10e
10f
10g
10a
12a
12b
12c
12d
12e
12f
12g
12a
12
X
T

FIG. 1

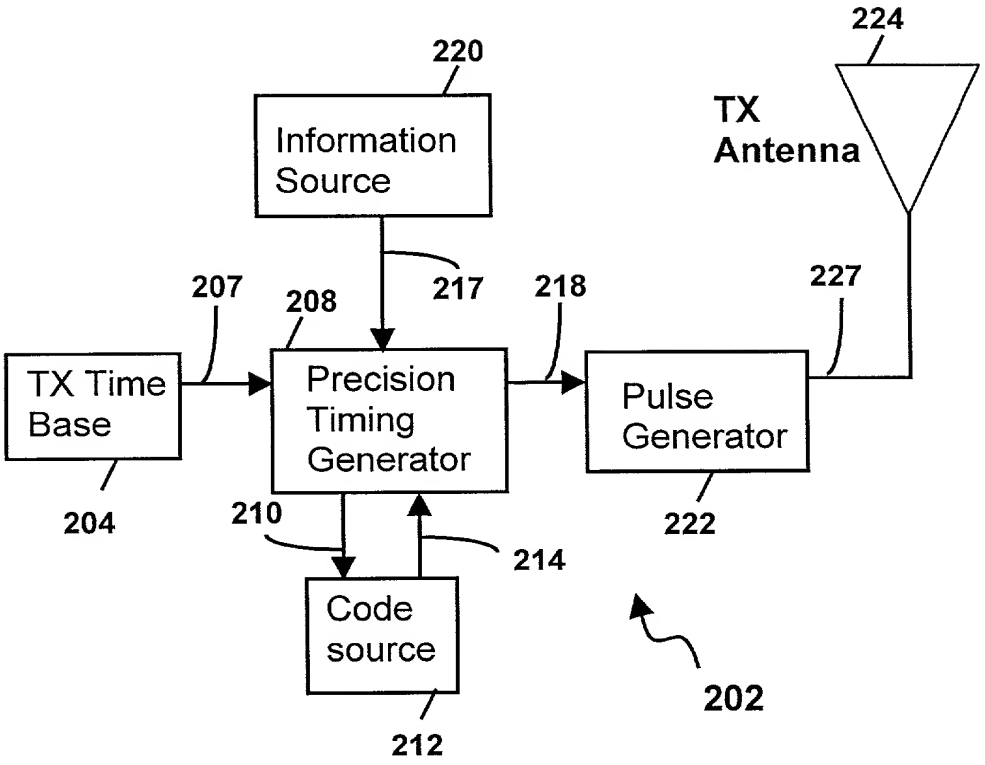

224
220
TX
Antenna
Information
Source
207
208
217
218
227
TX Time
Base
Precision
Timing
Generator
Pulse
Generator
204
210
214
222
Code
source
202
212

FIG. 2

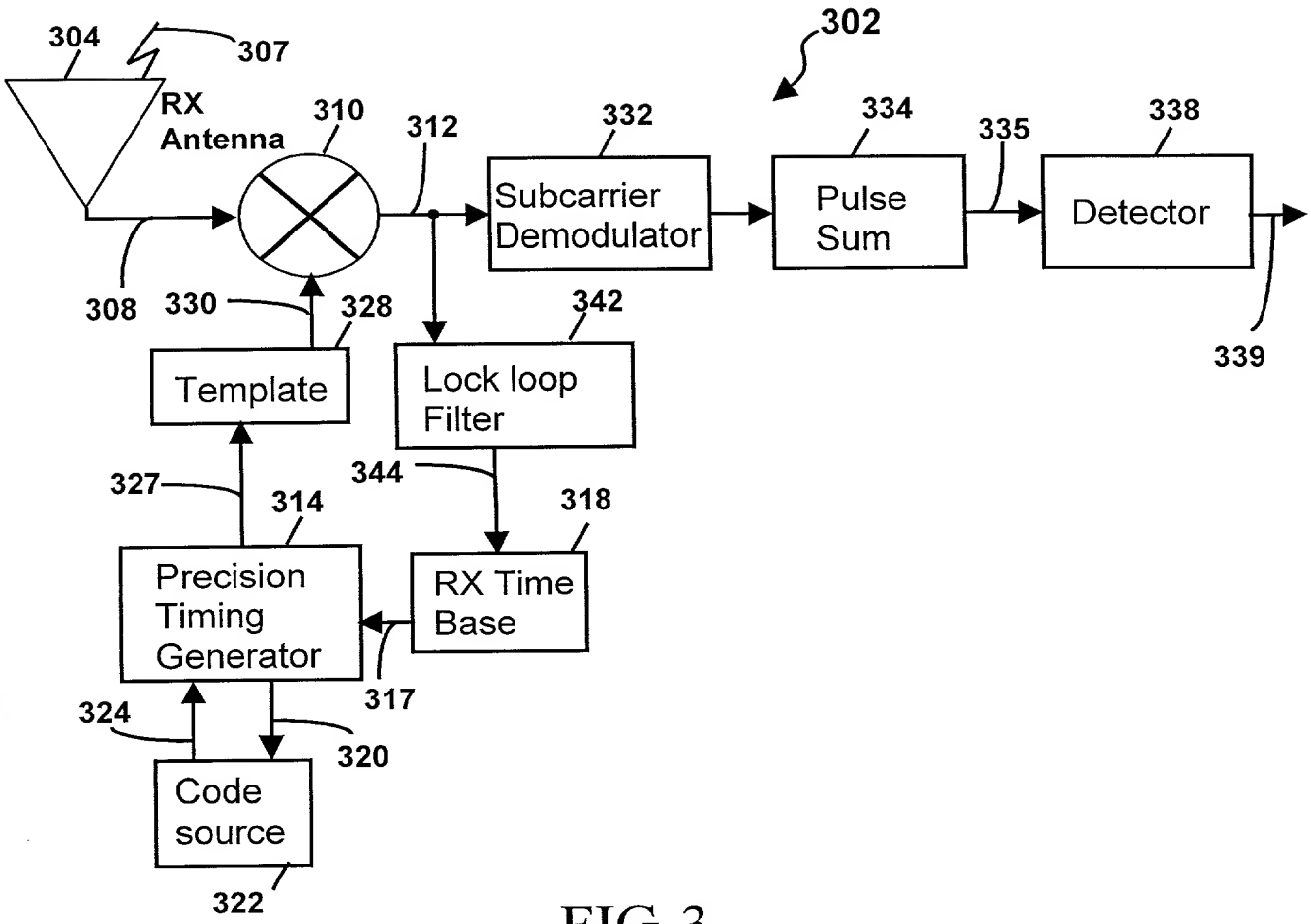

304
307
302
RX
Antenna
310
312
332
334
335
338
Subcarrier
Demodulator
Pulse
Sum
Detector
308
330
328
342
339
Template
Lock loop
Filter
327
344
314
318
Precision
Timing
Generator
RX Time
Base
317
324
320
Code
source
322

FIG. 3

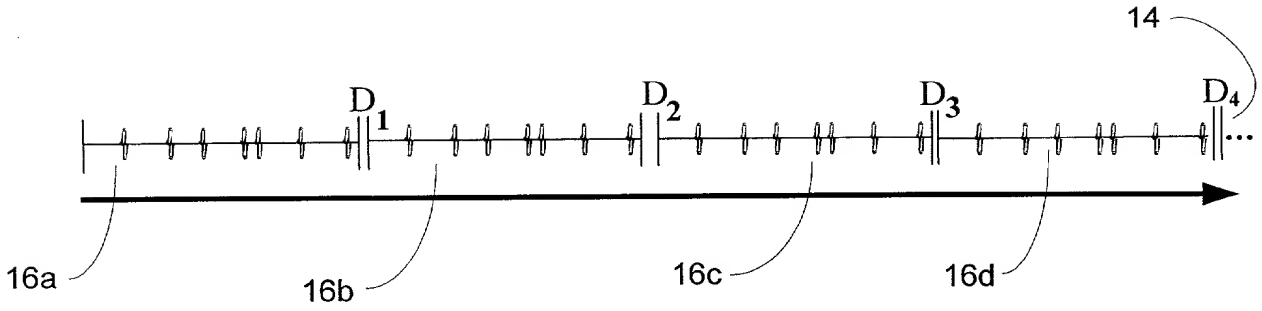


FIG. 4a

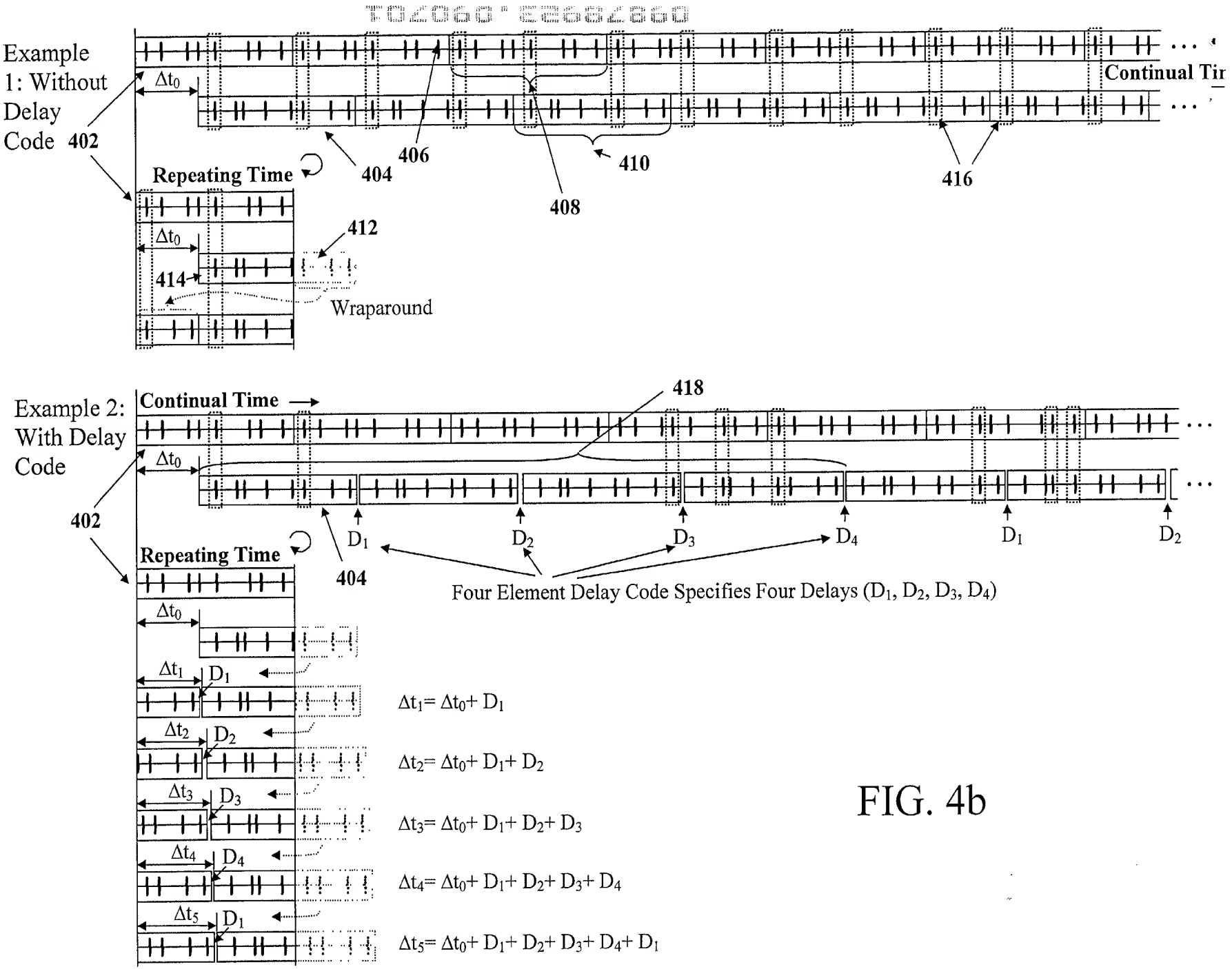

Example 1: Without Delay Code
402
Δt0
Repeating Time
404
406
408
410
412
414
416
Wraparound
Continual Tir
Example 2: With Delay Code
Continual Time
418
D1
D2
D3
D4
Four Element Delay Code Specifies Four Delays (D1, D2, D3, D4)
Δt1
Δt2
Δt3
Δt4
Δt5
Δt1= Δt0+ D1
Δt2= Δt0+ D1+ D2
Δt3= Δt0+ D1+ D2+ D3
Δt4= Δt0+ D1+ D2+ D3+ D4
Δt5= Δt0+ D1+ D2+ D3+ D4+ D1

FIG. 4b

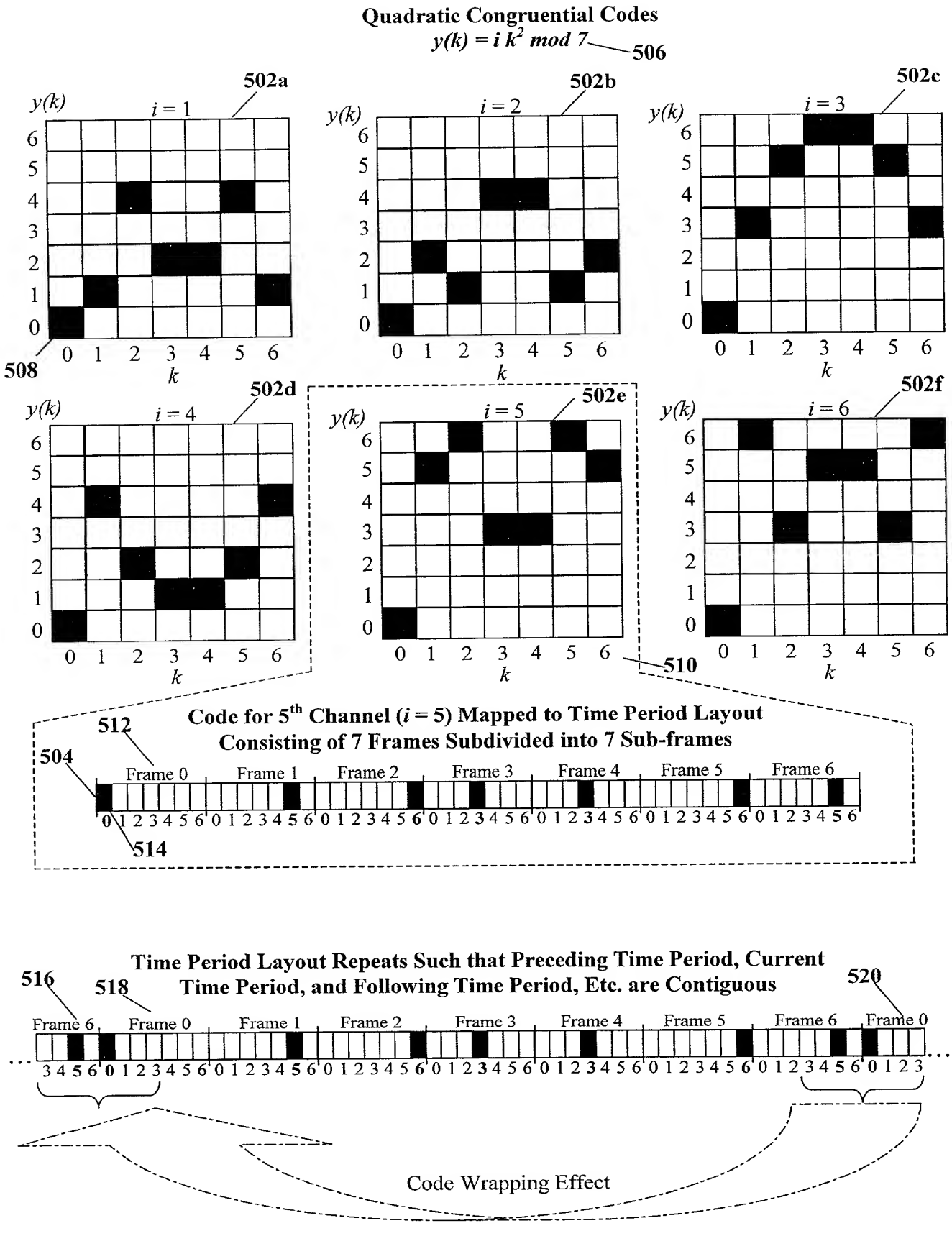

Quadratic Congruential Codes
y(k) = i k^2 mod 7
506
502a
502b
502c
502d
502e
502f
y(k)
i = 1
i = 2
i = 3
i = 4
i = 5
i = 6
k
508
510
Code for 5th Channel (i = 5) Mapped to Time Period Layout
Consisting of 7 Frames Subdivided into 7 Sub-frames
512
504
514
Frame 0
Frame 1
Frame 2
Frame 3
Frame 4
Frame 5
Frame 6
Time Period Layout Repeats Such that Preceding Time Period, Current
Time Period, and Following Time Period, Etc. are Contiguous
516
518
520
Code Wrapping Effect

FIG. 5

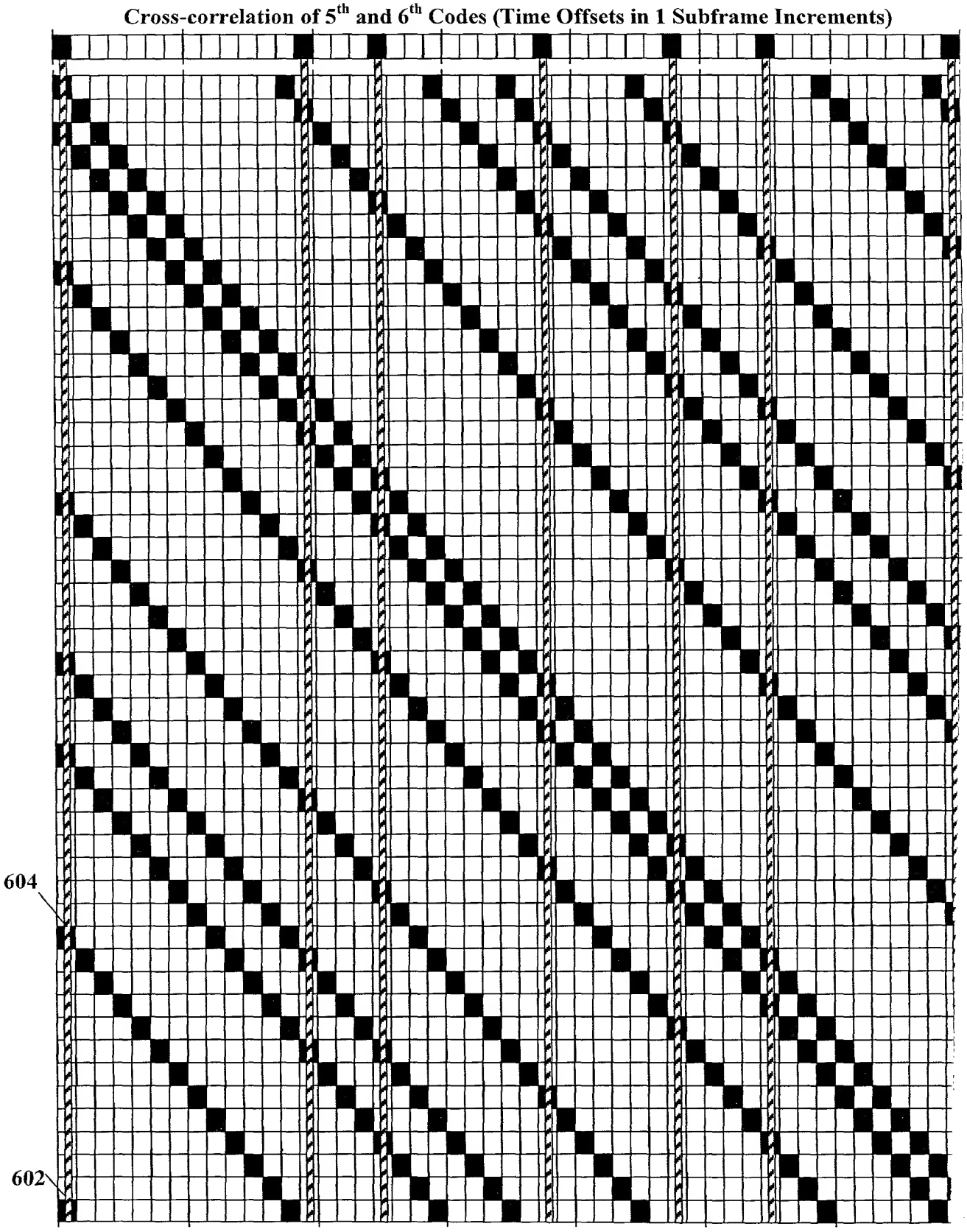

Cross-correlation of 5th and 6th Codes (Time Offsets in 1 Subframe Increments)
604
602

FIG. 6

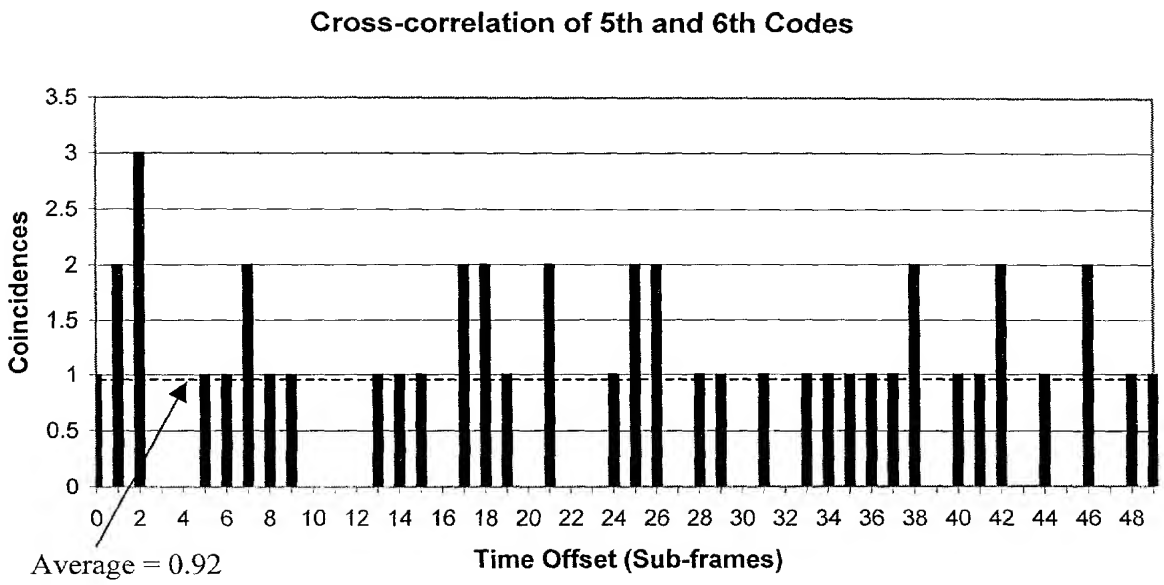

Cross-correlation of 5th and 6th Codes
Coincidences
3.5
3
2.5
2
1.5
1
0.5
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Time Offset (Sub-frames)
Average = 0.92

FIG. 7

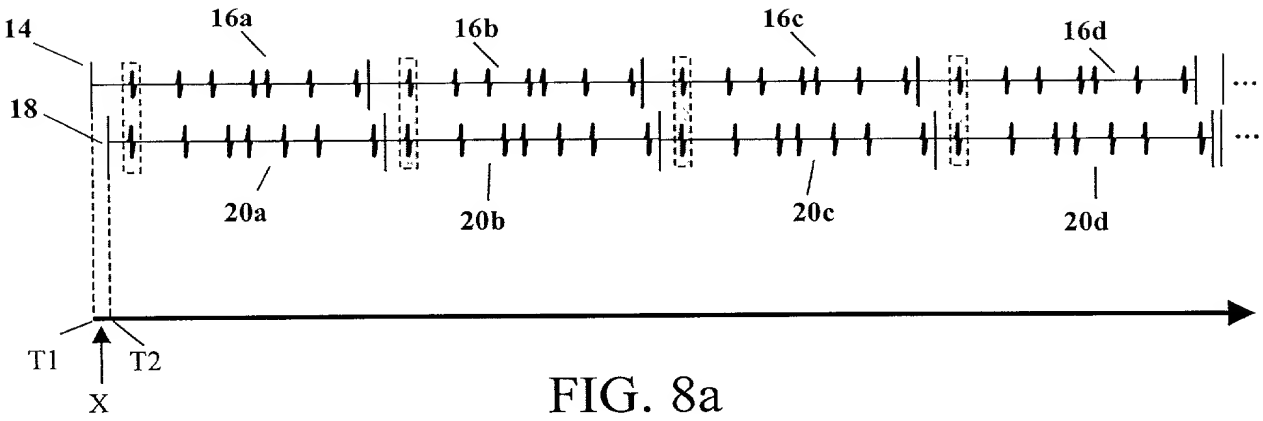

14
16a
16b
16c
16d
18
20a
20b
20c
20d
T1
T2
X

FIG. 8a

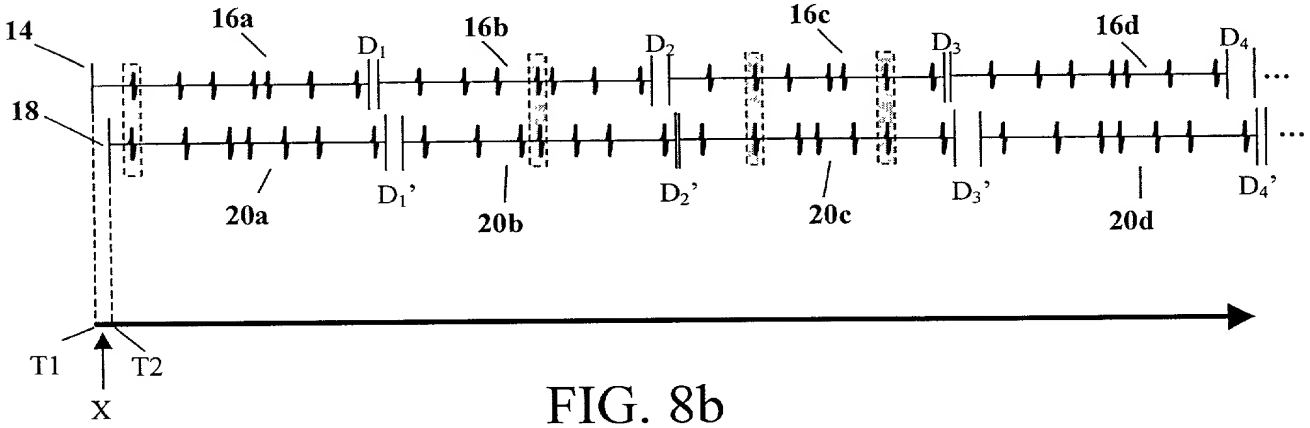

14
16a
16b
16c
16d
D1
D2
D3
D4
18
20a
D1'
20b
D2'
20c
D3'
20d
D4'
T1
T2
X

FIG. 8b

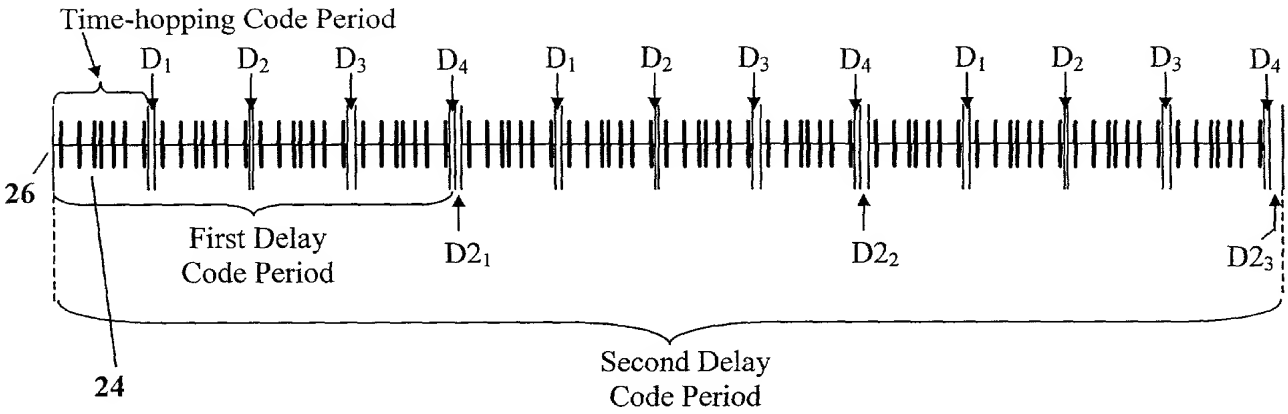
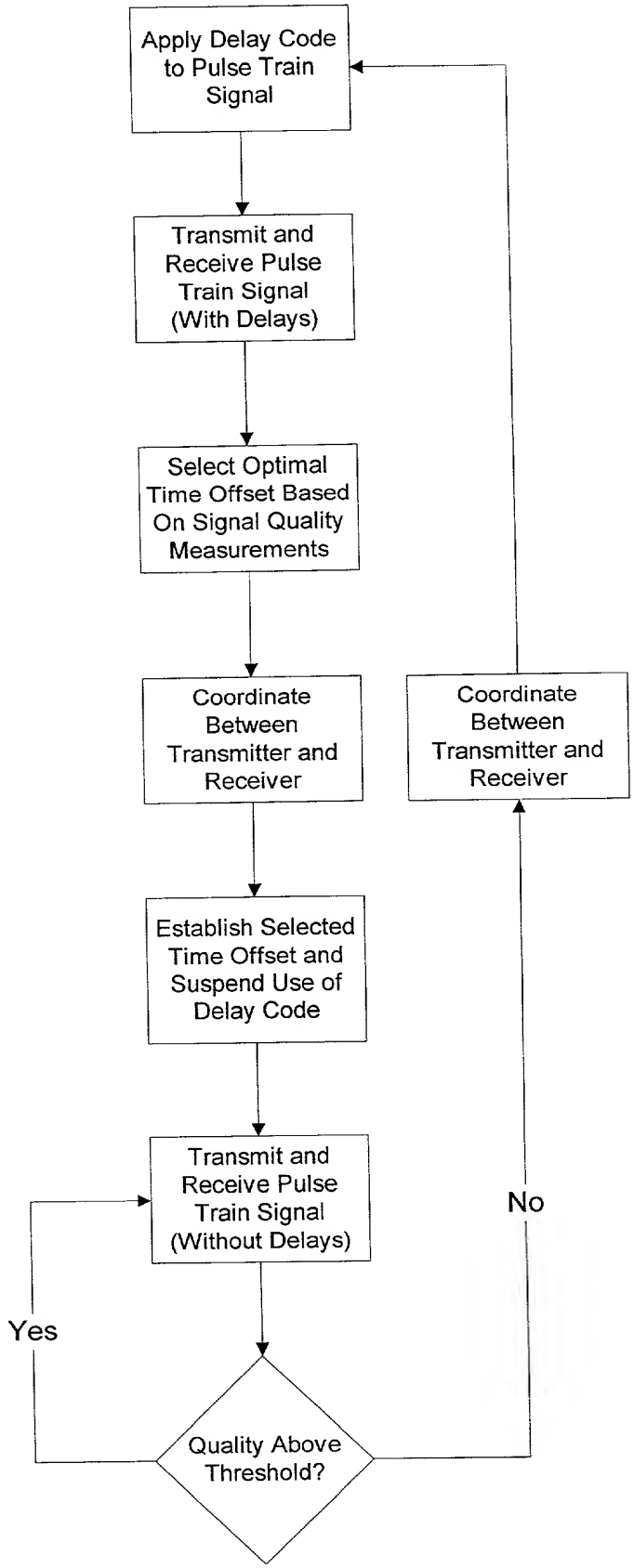

Time-hopping Code Period
D1
D2
D3
D4
D1
D2
D3
D4
D1
D2
D3
D4
26
First Delay
Code Period
D21
D22
D23
24
Second Delay
Code Period

FIG. 9

FIG. 10


Apply Delay Code to Pulse Train Signal
Transmit and Receive Pulse Train Signal (With Delays)
Select Optimal Time Offset Based On Signal Quality Measurements
Coordinate Between Transmitter and Receiver
Establish Selected Time Offset and Suspend Use of Delay Code
Transmit and Receive Pulse Train Signal (Without Delays)
Quality Above Threshold?
Yes
No
Coordinate Between Transmitter and Receiver